루프레이아웃AGVS에서의 작업요구 응답확률을 최대화 하기 위한 AGV 대기위치 결정 모형
(POSITIONING MODEL OF THE AUTOMATED GUIDED VEHICLE IN LOOP LAYOUT TO MAXIMIZE THE REQUEST-CALL RESPONSE PROBABILITIES)

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ABSTRACT

It is discussed how to determine the home location of idle vehicles in an AGVS with a loop guidepath in a way of maximizing the request-call response probabilities for all demand. Optimal home position is selected by solving the simultaneous equations easily. Static positioning strategy is analyzed in which a single home position is allocated to which every vehicle is routed whenever it becomes idle. The cases of unidirectional guidepath is considered only. We provide a numerical example to illustrate the search algorithm developed for the case and compare the searched optimal solutions with the others.

Key words : AGVS, loop guidepath, positioning, home position

Ⅰ. INTRODUCTION

The use of automated guided vehicles(AGVs) in material handling has been on the increase since the late 1970s. This is due to the proven performance of automated guided vehicles as reported by vendors and users of the system. Among the many advantages credited to the use of AGV systems(AGVS) are flexibility, increased productivity, reliability, safety, and improved housekeeping.

Although flexible in use, achievement of high performance for an AGVs is influenced by several operating factors largely. Among these the problem of idle vehicles positioning influences on the system's performance also [2,4]. Therefore, in this paper the problem of idle vehicle positioning is addressed.

When an AGV completes a delivery task and is not assigned any immediate pickup task, it becomes idle. One of the operational issues on AGVS that have not received much attention is where to locate or position the idle vehicle in anticipation of a pickup call from some workstation.

According to the literature on AGVS [1,2,4], the following rules are commonly used to position idle vehicles:

1) Central zone positioning rule:
One or more staging areas on the guidepath network are designated for buffering all the idle vehicles. When a vehicle becomes idle, it is routed to the staging area regardless of the location of the idle vehicle at that time.

2) Circulatory loop positioning rule:
One or more loops on the guidepath network are designated as circulatory positioning loops where idle vehicles continue to circulate until they are reassigned to new tasks.

3) *Point of release positioning rule:*

When a vehicle becomes idle, it remains at the point of release until it is reassigned to a new task.

In this paper, we analyze the problem of locating the central zone for positioning idle vehicles.
Studies on AGV positioning methodologies have been performed by Egbelu[2],Kim[4] and Song[5].
Egbelu[2] formulated a linear programming model based on the objective of minimizing the maximum vehicle travel time to reach the pickup location from the home position. Both bi-directional and unidirectional loops with single and multiple vehicles were studied. Kim[5] suggested a methodology to determine the home position of idle vehicles in an AGVS with a loop guide path. In his paper, the mean response time for a pickup call is minimized. Static and dynamic central zone positioning strategies were analyzed and both the bi-directional and unidirectional guide path were considered. Song et al.[5] considered the waiting queue length in the input buffer of each workstation to determine the home position of idle vehicles.
Egbelu[2] and Kim[4] suggested three objectives that may be used in selecting home position as follows:

1) Minimization of maximum vehicle response time
2) Minimization of mean vehicle response time
3) Even distribution of idle vehicles in the network

The response time means the empty travel time of a vehicle from the home position to the load pickup point which requests a delivery.
In most of real world application of manufacturing systems, the average service time of AGVS is the more popular criteria to evaluate operation strategies of AGVS than the maximum service time which is often validated in the cases of emergency services[4]. And since the service time consists of the waiting time for the vehicle assignment, the empty travel time and the loaded travel time, the average response (empty travel) time is a reasonable criteria for determining the home location of vehicles.
In this paper, we consider AGVS with a loop guidepath layout which is frequently utilized in practice because of its operational simplicity.
A loop layout is a guidepath network which is made of a single circuit and around which all the workstations served by the vehicles are located.
In this paper, the single vehicle unidirectional guidepath is considered only.
For the unidirectional guidepath, holding sidings for idle vehicles are necessary in the network.
In the next section, it is discussed how to locate a single home position to which every vehicle is directed whenever it becomes idle.

II. THE PROBLEM OF LOCATING A HOME POSITION

In this section, the problem of locating a static home position for idle vehicles in a loop layout guidepath is discussed. We mean by "static" that we allocate a path segment on the guidepath which all the idle vehicles are routed to and is not changed until it is relocated[4].
A Typical loop layout is shown in figure 1.

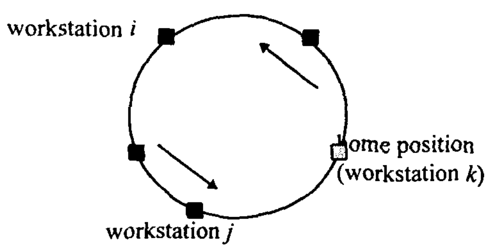

Figure 1. Typical loop layout guidepath

2.1 Assumptions

In order to formulate a mathematical model, we assume followings:

(1) Unidirectional guide path is assumed.
(2) Any call can not be received on an arc between node and node.
(3) Inter-call arrival time is the exponential distribution.
(4) Vehicle's travel direction is counter-clockwise.
(5) Waiting orders are limited.
(6) Home position corresponds to a location of arbitrary workstation.

In our model, we can address vehicle's operating types as followings.

case 1 : There is a waiting request-call. Vehicle starts to a waiting request-call(next request-call) immediately after work ending on node i,
case 2 : There is no a waiting request-call and no new request-call during vehicle's returning to a specific home position node after work ending on node i,
case 3 : There is no a waiting request-call and a new request-call during vehicle's returning to a specific home position node after work ending on node i,

case 3.1 : There is no a waiting request-call and a new request-call on any node during vehicle's returning to a specific home position node after work ending on node i,
case 3.2 : There is no a waiting request-call and a new request-call on any arc during vehicle's returning to a specific home position node after work ending on node i.

We mean a "request-call" by a request for pickup and delivery that any workstation produced. In this paper, we will consider all the cases except case 3.2.

2.2 Notations

The following notations are introduced to model:

n : the number of nodes(node includes the arbitrary station, pickup or delivery point of a station),
h : node number of home position,
t : the vehicle traveling time t,
v : the travel velocity of the vehicles,
$f(t) = \lambda e^{-\lambda t}$: the inter-call time distribution,
$F(t) = 1 - e^{-\lambda t}$: the call probability before time t,
$1 - F(t) = e^{-\lambda t}$: the call probability after time t,
if $t_1 > t_2$,
$F(t_1, t_2) = F(t_1) - F(t_2) = e^{-\lambda t_2} - e^{-\lambda t_1}$: the call probability between time t_1 and t_2,
E_i : the probability that a specific work-request is ended on node i,
S_i : the probability that a vehicle will start to a waiting request-call(next request-call) immediately after work ending on node i,
M_{ij} : the probability that a vehicle will receive a request-call on node j after work ending on node i,
R_i : the probability that a vehicle will receive a request-call during waiting at home position after work ending on node i,
D_{ij} : vehicle's minimum travel time from node i to node j,
P_{ki} : the probability that next pickup request is on the path k to i among a work is ended on node i,
T : a complete turn-around travel time of the vehicle on the loop guide path,
f_{ij} : the flow quantities from node i to node j,
d_{ij} : vehicle's minimum travel distance from node i to node j,

P_i : the probability that the next pickup request is issued by workstation or load source i.

2.3 The Model in case of unidirectional guide path

Since the control becomes very complicated for the case of bi-directional path, most of AGVS consist of unidirectional guidepaths. Let's assume that the guidepath is oriented in the counterclockwise direction.

The resulted each probability can be estimated as following expressions.

$$E_i = \frac{\sum_{j=1}^{n} f_{ji}}{\sum_{i=1}^{n}\sum_{j=1}^{n} f_{ij}}$$

$$S_i = E_i \sum_{\substack{k=1 \\ k\neq\{p\}}}^{n} \left[S_k F(D_{ki}) + \sum_{j>k}^{h} M_{kj} F(D_{ji}) + R_k F(D_{hi}) \right]$$

$$M_{ij} = E_i \sum_{\substack{k=1 \\ k\neq\{p\}}}^{n} \left[S_k F(D_{kj}, D_{k(j-1)}) + \sum_{u>k}^{h} M_{ku} F(D_{uj}, D_{u(j-1)}) + R_k F(D_{hj}, D_{h(j-1)}) \right]$$

$$R_i = E_i \sum_{\substack{k=1 \\ k\neq\{p\}}}^{n} \left[S_k (1 - F(D_{kh})) + \sum_{j>k}^{h} M_{kj} (1 - F(D_{jh})) + R_k (1 - F(D_{hh})) \right]$$

Therefore, we can select a candidate node having maximum total call probability as a optimal home position.

2.4 Solving procedures

1) Ready data and read
   . vehicle speed(v) = m/sec
   . demand arrival rate(λ) = demand/sec
   . inter-call distribution : exponential(λ)
   . node-to-node flow quantity & distance matrix

2) Convert original data
   2.1) Counter-clockwise node number indexing using a arbitrary reference node.
      . n : total number of nodes(= maximum node number)

   2.2) Creation of travel time matrix and demand call probability
      . total loop length : TL
      . complete turn-around travel time(T) = $\frac{TL}{v}$
      . node to node travel time = $\frac{d_{ij}}{v}$
      . demand call probability function (exponential λ)

3) Initialization

   3.1)Let pickup node only set to $\{p\}$, delivery node only set to $\{d\}$
      and pickup/delivery node set $\{pd\}$.
      Let loop node set as $\{ns\}=\{1,2,3,.....,n\}$.

3.2) If $\{ns\} = \varnothing$, go to 10).
Otherwise, select node i as a home position and set $h = i$, $\{ns\} \leftarrow \{ns\} - \{h\}$

4) Calculate E_i, P_{ki}

$$P_{ki} = \frac{d_{ki}}{TL}, \quad i \in \{d\} \cup \{pd\}$$

5) Elimination

. if node i is the pickup node only or selected home position node, all M_{ij}, S_i, R_i , $i \neq j$ are eliminated.

. all M_{ii} are eliminated.

7) Equation enumeration and modifying procedures

step 1: select a element with $F(D_{ij}, D_{kl})$, $D_{ij} \langle D_{kl}$ in M_{ij} equations

step 2: set $D_{ij} \leftarrow T + D_{ij}$

step 3: search all element(S_i, M_{ij}, R_i) included the first entry D_{ij} for equation element i of (M_{ij}, R_i)

step 4: set the entry value to $D_{ij} \leftarrow T + D_{ij}$
if modified entry is second entry,
set the first entry to $D_{ij} \leftarrow T + D_{ij}$

step 5: if all equation element i is searched, Stop.
Otherwise, go to **step 4**.

8) Solve the resulted simultaneous equations.

9) From the resulted solution value, calculate the $\{ \Sigma \Sigma_{j \neq h} M_{ij} + \Sigma R_i \}$ and set this value to RCP_h
Go to 3.2).

10) Select node h as a optimal home position which has the maximum RCP_h.

2.5 A Numerical example

A numerical example is solved using the data in Kim[4]. We assume that the direction of guidepath is counterclockwise. And the reference point is P/D_1.

Ⅲ. CONCLUSION

Determination of the home location for idle vehicles is one of important issues in the operation of AGVS, since it significantly affects the service time of AGVS for a load pickup request.

In this paper, we treated the problem of home location selection for the cases of static positioning where a single home position is designated to which every vehicle is routed whenever it becomes idle.

And the unidirectional guidepath is considered. Mathematical models are formulated and an efficient procedures is suggested for each case.

A numerical example is given to demonstrate the applications of the procedures developed.

REFERENCES

1. Co, G. Christine and Tanchoco, J. M. A., 1991. A review of research on AGVS vehicle management. Eng. Costs Prod. Econ., 21, pp.35-42.

2. Egbelu, P. J., 1991. Positioning of automated guided vehicles in a loop layout to improve response time. IMSE Working Paper 91-104, Department of Industrial and Management Systems Engineering, The Pennsylvania State University.
3. Francis, R. L., McGinnis, Jr., L.F., and White, J.A., 1992. Facility Layout and Location : An Analytical Approach. Prentice Hall, pp.427.
4. Kim, K. H., 1995. Positioning of automated guided vehicles in a loop layout to minimize the mean vehicle response time, Int. J. of Production Economics, Vol.39, pp.201-214
5. Song, S..H., Choi, H.J. and Cho, M.S., 1996. A Study on the Decision Policy for the Waiting Position of an Idle AGV, Journal of the Korean Institute of Industrial Engineers, Vol.22 No.3, pp.313-324.